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EXTENSIVE AND INTENSIVE TROUT FARMING IN FRESH PONDS IN SASKATCHEWAN: WATER QUALITY REQUIREMENTS

by

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EXTENSIVE AND INTENSIVE TROUT FARMING IN FRESH WATER PONDS IN SASKATCHEWAN: WATER QUALITY REQUIREMENTS

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ABSTRACT: Very little attention has been paid to water quality parameters for extensive trout farming in fresh water. The basic criteria was a minimum of 8 ft. (2.4 m) of water in the fall, low level algae, and adequate natural food. This translated to 300-400 fish per surface acre (0.4 ha). The problems of poor fall recovery, muddy taste, summer-kill, poor growth, predators and poachers were the risks of trout farming. Until the advent of cage rearing in intensive fish culture these risks were never addressed. In most cases, any real push for market penetration of a high protein product was neglected. Now we are beginning to understand and identify some of the warning signs, causes, and counteractions which reduce risks and improve product quality and profitability. The parameters of nitrogen tension, pH, ammonia, nitrite, hardness, clarity, carbon dioxide, oxygen, and temperature must be monitored. Other considerations include feed control, ground waters, run-off, pesticides and algae control.

Extensive Trout Farming

Trout farming in Saskatchewan was introduced primarily between 1968 and 1972. Collection of statistical data began in 1970 with 144 private licencees, 22 in commercial extensive trout farming (1). Today we have 2200 trout farmers of which 92 are commercial. It has been observed that the average return from stocked water bodies is 35%. There are a number of reasons for this poor recovery: predators, wrong size or limited size of gill nets, improperly set nets, starting harvest too late in the season, poaching, summer kill, transportation stress, or water chemistry problems at planting time.

The basic requirements for trout farming in Saskatchewan ponds has been very basic. A minimum water level of 8 feet (2.4 m) in the fall, adequate natural feed (fresh water shrimp), low algae levels, with no exits or entrances that fish may escape out of.

Where stocked waters have been favorable, growth has varied from 10-14" (25.4 - 35.5 cm) between May 1st and October 1st or approximately 153 days from 4" (10 cm) fingerlings. Flesh is orange/pink from feeding on the fresh water shrimp that are abundant in the prairie ponds. Trout from approximately 35% of all extensive fish farming ponds have a muddy taste.

Water quality has not been emphasized adequately. Basic thinking in the past has been to stock some fingerlings in the pond, forget about them all summer and pull them out in the fall with gill nets. This philosophy infers no cost, no hassles, and all profit. Unfortunately, this is not the case.

Oxygen in Trout Transportation

Transportation stress probably accounts for 40% of all stocked trout pond failures in Saskatchewan. One water quality parameter we seldom consider is elevated oxygen. Experiments at the Saskatchewan Research Council's Aquaculture Field Laboratory on fish transportation stresses indicate that oxygen supersaturation, which causes gas bladder disease, can be just as serious as inadequate oxygen. Whether fish are transported in plastic bags of water with oxygen pressurization or transported in tanks, oxygen supersaturation that trout can tolerate has a limit. In transportation tanks, if oxygen levels stay between 12-18 ppm there are no apparent problems with the fish. Measurements taken in plastic bags of water that have been pressurized with oxygen, without monitoring, may have levels of oxygen in excess of 20 ppm. At temperatures of about 9^{o}C and elevations of approximately 1600 ft. (488 m), this oxygen level would be 175% saturation or more. Fish exposed to supersaturation levels above 160% display stress by loss of equilibrium such as vertical movement upwards, or on their backs with vigorous movement. The degree of supersaturation is dependent upon water temperature and altitude. Fish transported at oxygen levels of 12-18 ppm, and temperatures of 9^{o}C fair well for at least eight hours.

Oxygen Acclimatization

Oxygen levels should be nearly the same in both water columns and then slowly increased or decreased as required. Experiments with pond oxygen levels of 12 ppm and tank oxygen levels of 18 ppm indicate that if the tank oxygen is slowly reduced to 12 ppm over three quarters of

an hour, no visible stress of the fish and no post mortality in holding cages occurs. When trout were not climatized, 90% mortality was encurred.

Groundwater and Oxygen

Whether dispersed in the pond or held for a short period in cages, some trout farmers have experienced mortality of fish within 24 hours of planting fingerlings. In two specific cases the ponds were fed from several springs from below the water level, with a fair discharge out of the ponds. The fingerlings in each case died within 24 hours. Water samples were taken and pH, ammonia, nitrite, hardness, alkalinity and iron were measured. None of these measurements indicated a problem. No algae was noted. In measuring the oxygen and temperature, the water was found to have 1.2 ppm of oxygen at a temperature of 7^{o}C. Springs flowing into a pond from below the water level contain little or no oxygen.

Photosynthesis, Oxygen and Supersaturation

When algae levels develop in ponds during the spring, even before the ice breaks up, increased levels of oxygen and nitrogen may very well kill off a population of trout that otherwise have wintered well. During normal daylight hours algae produces oxygen by photosynthesis. If algae activity is high, oxygen levels can become very high. We have measured levels of oxygen in excess of 20 ppm with water temperatures of 21^{o}C, or 235% saturation.

Summer Kill

During the night the algae consume oxygen and produce carbon dioxide. If the net loss of oxygen is greater than the daytime gain then the algae will die off suddenly and a collapse of the pond takes place. Soon after this takes place oxygen levels are so low that fish begin to die. When Secci disc readings are still visible to a depth of 2 feet (600 mm), treatment of the pond can be carried out to reduce the algae levels. This is done by spreading copper sulphate evenly over the pond using a treatment rate of 1.5 pounds (680 g) per surface acre (0.4 ha). If visibility is less than stated there is a danger of causing an algae collapse, thus a summer kill. Hot, cloudy weather, with little or no wind appears to help initiate a collapse.

Winter Kill

When a pond freezes over oxygen transfer from the atmosphere ceases. Wind action and mixing is no longer a contributing factor to the well-being of the pond as far as oxygen is concerned. As long as there is little or no snow cover a low level of photosynthesis continues. When snow blocks off most of the short winter daylight periods algae dies off and oxygen levels slowly fall. If oxygen falls below 3 ppm fish-kill results. The Aquaculture Centre began overwintering extensive trout-farmed fish with very high survival in 1981 and 1982. On a 45 acre pond (18 ha) they managed the algae levels with copper sulphate in the summer, vented the lake in the winter with a pond mill, and removed 20% of the snow cover. When this procedure was stopped, there was complete winter kill in 1983.

Water Parameters

Before ponds are stocked with trout, the following should be checked: oxygen, pH, total ammonia, iron, and nitrite. Oxygen should not fall below 5 ppm for good fish health. pH should be between 6.5 and 9.0; total ammonia must be below 1 ppm. Nitrites usually are not a problem but if ammonia levels are high, nitrite levels could be elevated. Iron should not exceed 0.3 ppm, hardness from 20 ppm to as high as 2000 can be tolerated, with alkalinity between 30 ppm and 500 ppm. The acclimation of trout from one water body to another must be done with these parameters in mind. The slower the acclimation the less stress on the fish. Table 1 indicates the pH-ammonia-temperature relationship.

Various ponds in northern Saskatchewan have shown elevated levels of pH and ammonia as shown in Table 2.

In each case where high levels of total ammonia and pH were observed, serious, if not total mortality took place during the summer, late fall, or early spring. This loss is not always due to low oxygen levels. Gill damage was evident, with severe clubbing of the gill filaments, in some cases severe eye cataracts have been observed due to high pH exposure over long periods. It is suspected that in some cases fish with gill damage from ammonia cannot function at lower oxygen levels that otherwise would not present a problem.

Table 3 illustrates another area of trouble for both extensive and intensive trout farming when algae builds to a level of collapse.

Our G1 45 acre (18 ha) lake has been used for eight years for extensive trout farming with 1500 fingerlings planted in 1974 to 20,000

CONCENTRATION OF TOTAL AMMONIA
HAVING .02 MG/L NH3

Temp.	pH		
C	7.5	8.0	8.5
5	5.1	1.6	.53
10	3.4	1.1	.36
15	2.3	.75	.25
20	1.6	.52	.18

These values indicate when a water column exceeds .02 mg/L of NH3 - which is considered the highest HEALTHY level for trout. (condensed from Thurston et al tables)

TABLE 1

CAGE CULTURE

WATER CHEMISTRY

LOCATION	TEMP. C	OXYGEN ppm	pH	AMMONIA TOTAL ppm	NITRITE TOATAL ppm	DATE
Sturgeon Dugout	21.0	7 ppm	8.2	.45	0	July 8/85
D.B.Pond	21.1	7.7 - 5 ppm	8.0	.8	0	July 8/85
Rainbow Lake	21.5	9.1 - 8.5 ppm	8.15	.2	0	July 8/85
Greywater Pond	21.0	8.8 - 9 ppm	9.4	.5	0	July 8/85
Boulder Pond	21.0	-	9.1	.3	0	July 9/85

Cage culture ponds in northern Sask. Mortalities occurred in D.B.Pond and Greywater Pond in August and October. Boulder Pond was an extensive culture pond this year.

Table 2

G1 CAGE CULTURE

pH	N ppm	Temp C	Oxygen ppm	Secchi mm	Algae level	Date	Mort
		16.0	7.2			5/24/85	4
8.7		13.9	9.2			6/04/85	
8.6		14.5	8.8	510		6/10/85	
		14.2	8.6	500		6/18/85	2
		16.0	6.8	1000		6/25/85	1
						6/26/85	3
					med.	7/03/85	
8.75	.4	20.1	7.4	1000		7/05/85	
		21.4	7.5			7/09/85	
8.4		21.2	5.6	1500		7/11/85	1
	Copper sulphate treated				med.	7/12/85	3
8.45		20.9	5.7	1400	high	7/14/85	
8.5		21.2	8.1	1250	high	7/15/85	
8.7		21	6.4	1200	high	7/16/85	
8.6		19.4	6.9	1200	high	7/18/85	
8.75		19.2	7.0	1000	high	7/20/85	
8.85		19.9	10.2	1000	high	7/21/85	
		20.0	10.5	2258	high	7/24/85	
9.1		20.1	11.4		med.	7/26/85	
8.95		18.6	6.8	1000	med.	7/28/85	
8.9		19.0	9.7	1250		7/30/85	
8.9		20.0	6.0	1750	low	8/01/85	
8.58	1.5	21.1	$ 4.2	1900	low	8/03/85	13
8.5	1	21.2	$ 2.6	2030	low	8/04/85	2
8.75		21.0	$ 3.0	1800	med.	8/05/85	10
		19.2	$$ 2.4	1800	med.	8/06/85	637
8.8		19.2	$$ 2.6	1500	med.	8/07/85	30
8.8		19.7	$$ 3.0	1500	med.	8/08/85	5
8.7		17.8	$$ 2.6	1500	low	8/09/85	1
8.55		17.9	$$ 3.3	2000	low	8/10/85	
8.45		17.8	$$ 3.6	1800	med.	8/11/85	
8.7		17.0	$$ 2.0	1500	med.	8/13/85	7
		16.5	$$ 4.0	1250	high	8/14/85	2
8.45		16.9	$$ 4.7	600	high	8/16/85	3
8.55		16.7	$$ 4.0	900	high	8/18/85	1
8.4		16.1	$$ 6.0	820	high	8/19/85	
8.65		16.1	$$ 6.8	1000	high	8/21/85	
8.65		15.9	$$ 5.2	800	high	8/23/85	1
8.5		17.4	$$ 6.0	700	high	8/25/85	
8.65		16	$ 5.2	920	med.	8/27/85	
8.75		15.7	$ 6.0	900	med.	8/29/85	
8.6		16.2	$$ 5.6	500	high	8/31/85	
8.4		16.2	$$ 7.5	730	high	9/02/85	
8.85		16	$$ 6.2	870	high	9/04/85	
8.8		14.3	$$ 6.4	500	high	9/06/85	
8.55		12.8	$$ 5.6	500	med.	9/08/85	
8.7		12.3	$$ 5.7	800	med.	9/10/85	

pH	N ppm	Temp C		Oxygen ppm	Secchi mm	Algae level	Date	Mort
8.2		13.0		6.0	700	med.	9/12/85	
8.45		13.0		7.2	500	med.	9/14/85	
8.7		12.2	$	6.6	900	low	9/16/85	
8.75			$$		600	low	9/18/85	
8.75		10.1	$$	6.4	620	low	9/21/85	
			$			low	9/23/85	
8.65		7.0	$	8.2	1000	low	9/26/85	
8.77		5.9	$$	2.3	500	low	9/28/85	
8.6		2.0	$$	9.2	600	low	9/30/85	
		3.5	$$	9.2			10/02/85	
8.75		6.0	$$	9.1	520	low	10/05/85	
		5.2	$$	10.5		low	10/07/85	
8.7		3.5	$$	11.6	800	low	10/10/85	
8.9		4.0	$$	9.4	750	low	10/12/85	
8.75	.6	4.1	$$	10.3	600	low	10/13/85	

G1 Lake - 45 acres, cage culture, and extensive culture.
Mortality only for cage operation. ($ $$ denotes aerator/aerators operating.)
N - Total Ammonia/Nitrogen.

Table 3

in 1981. Algae has gradually become more prolific each year, to the point of choking out shore plant growth. We placed 1400 8 inch (20 cm) trout in a 12 ft. x 12 ft. x 6 ft. (3.6 m x 3.6 m x 1.8 m) cage, and another 18,000 3.5 inch (8.9 cm) fingerlings in the lake on May 23, 1985. By June 26th the fingerlings were 5.4 inches (13.7 cm). This lake had been treated with copper sulphate at the rate of 1.5 lb/surface acre (0.6 kg/0.4 ha) twice in early May to reduce algae build up.

Initial mortalities noted in Table 3 were due to transportation stress when oxygen adjustments were not carried out. As temperature rose, oxygen began to fall, algae blooms intensified, and on August 3rd mortalities began to show up in the cage. This peaked on August 6th. Out on the rest of the lake many dead trout were noted. Some were recovered and measured at 6-7.5 inches (15-19 cm). As the algae problem slowly receded, mortality ceased on August 23rd. During this stress period it was observed that the fish were not feeding.

The use of aerators in the cage certainly helps in the critical period of algae collapse as oxygen readings out in the unaerated area of the lake were even lower. If the aerators had been installed sooner, we may have been able to reduce or eliminate mortalities in the cage.

Iron

When well water is used to fill or top-up fish ponds, oxygen levels and iron levels can cause a mortality problem that is baffling to the fish farmer. In one case, in western Saskatchewan, a farmer planted trout in a pond which had about 5-6 feet (1.5 - 1.8 m) of water in

it, and began to fill the pond to approximately 10 feet (3 m) over a period of two weeks. In approximately eight days he noted the fish swimming close to the surface, and several days later they were all dead as a result of very low oxygen and gills that were 90% plugged with iron precipitate and mucous. Oxygen levels measured 4.6 ppm, temperature 8°C, and iron 1.4 ppm. Well water has little or no oxygen, and very often has levels of iron above the suggested level of 0.3 ppm. Oxygenating the well water with riffle bars and having a small settling pool could have prevented this problem.

pH

Sudden drops in pH can cause mortalities to trout as observed in the United States (2). For example, after thunderstorms fish are found dead in ponds in coal-stripping areas. By the time a conservation officer can get to the pond nothing is found by observation of the fish or by water chemistry measurements. Oxygen is normal, pH is normal, as are other parameters. Iron pyrite, associated with coal, has the ability to reduce pH very quickly by producing sulfuric acid when flushed with water and oxygen. If the birms or tailing piles are not grassed over, when heavy rains fall, the pH levels can fall from 7-8 to below 4 in a few hours, and then recover to normal levels in less than 48 hours due to the buffering action of the alkaline waters. In experiments with acid levels at our research facilities, a pH of 3-4 produces absolute mortality in trout, and even if they are removed from the low pH water and placed in pH 7 water, they do not recover. This problem has not surfaced as yet in Saskatchewan but we must be aware of the possibilities in our coal stripping areas of the south.

Off-Flavor

Muddy-flavored trout has been a problem in 35% of all ponds farmed in Saskatchewan. In recent years this has fallen to about 12% with the use of copper sulfate (bluestone). By applying 1.5 lbs. (0.68 kg) per surface acre (0.4 ha) to water with a mean depth of 8-10 feet (2.4-3.0 m), algae (Geosmin and certain blue greens) that are associated with muddy flavor can be controlled. It has been observed that treating the pond 14 days before harvest removes all traces of muddy taste (3).

Intensive Trout Farming

Cage rearing of trout began in Saskatchewan in 1982 at the Saskatchewan Research Council's Aquaculture Field Laboratory at Saskatoon (4). This program was geared towards the small pond or dugout that many trout farmers are using. Extensively, a 0.25 acre (0.1 ha) pond can support only 50-75 trout with its' natural feed supply. With cage culture, two cages with a volume of 301 cu. ft. (8.5 cu m) each can rear 1500 lbs. (680 kg) of trout, using demand feeders and a good quality of sinking trout feed. To insure a pink-fleshed product a pigment is introduced to the feed at manufacturing. We have found that a double pigment additive is the minimum requirement (800 g/tonne).

Pond Management

We recommend that two years of culture in the same 0.25 acre (0.1 ha) water column with a 1500 lb. (680 kg) production is all that should be attempted. The water has to be removed, the pond cleaned out, and new water replaced. Trying to continue into the third year with elev-

ated phosphorus levels results in poor growth. High ammonia, nitrite, and phosphorus levels coupled with algae proliferation beyond control are the limiting factors. Visibility for fish to feed properly in waters with high levels of algae is just one of the reasons of poor growth. Nutrient wastes from the trout and feed are beginning to show up in all extensive ponds and are certainly showing up in all intensive ponds. For every pound (454 g) of feed that a trout consumes, a third of a pound (150 g) of fecal material is produced, and just under a quarter of a pound of liquid nutrients is excreted, such as, phosphorus, and ammonia (5). Table 4 shows some of the water quality parameters to substantiate some of this claim, that have been observed in Saskatchewan Research Council ponds in the last two years.

Aeration

Over-wintering of small ponds using electric aerators has proven successful. Oxygen levels are completely mixed from top to bottom and end to end in the pond at 10 ppm. Aerators have also been used to lower supersaturation levels of oxygen and nitrogen, thus lowering ammonia levels as well. Table 5 shows some of the gas saturation problems at spring break up.

Nitrogen Supersaturation

Very high nitrogen supersaturation levels have been observed in the west pond at our research station. High pH values of 10 or more were always associated with this early spring problem. In 1985 fish losses were severe in the early spring, nitrogen levels of 140% were

pH	Ammonia Total ppm		Nitrite Total ppm	Secchi mm	Temp. C	Oxygen ppm	Date
8.3	.13	*		666	14.9	4.4	9/06/83
8.62	.39			228	6.8	12.6	4/30/84
8.7	.06			255	11.5	11.2	5/15/84
9.03	.3			750	14.8	9.5	6/13/84
8.3	.17			750	20.5	7.1	7/11/84
9.23	.15			370	20.5	12.0	8/17/84
8.27	.12			250	10.2	9.3	9/16/84
8.01	.47			300	7.0	5.2	10/14/84
10.44	.09	*			13.8	10.0	5/28/85
9.4	.1	no fish		300	19.0	5.9	7/15/85
7.82	1.2	no fish		250	19.0	8.7	7/30/85
7.32	2.2	no fish		1200	17.0	1.6	8/12/85
7.33	4.2	no fish		310	8.2	8.2	9/10/85
7.5	>3.0		.025	295	4.0	8.6	10/15/85
7.42	6.0			310	6.0	8.2	10/22/85
7.06	6.6			325	1.5	9.6	12/02/85
7.59	9.7			375	.5	11.0	1/10/86
7.11	11.0			395	0	11.9	2/11/86
7.88	12.0	*			0	11.5	3/04/86
7.37	14.0	*			.2	10.5	3/10/86
7.88	8.7	*		270	0	12.4	4/07/86
9.88	2.8			250	7.2	15 +	4/28/86
10.1	1.25		.15	200	8.8	10.8	4/29/86
10.3	1.05		.07	300	7.9	12.2	5/02/86

West Pond water quality records - * denotes observed mortality.

pH	Ammonia Total ppm		Nitrite Total ppm	Secchi mm	Temp. C	Oxygen ppm	Date
8.4	.17			100	14.8	7.8	9/06/83
8.9	.03	refilled pond		300	11.2	8.5	5/13/84
7.98	.05			480	14.0	8.3	6/13/84
8.37	.34			750	20.0	8.3	7/11/84
8.7	.21			300	19.8	8.3	8/17/84
7.67	.70			300	10.0	10.3	9/16/84
7.87	.37			250	8.0	5.7	10/14/84
8.7	.29			250	20.0	7.8	7/15/85
8.82	.45		.198	180	18.5	7.6	7/30/85
7.75	.58			400	17.5	5.7	8/12/85
6.63	1.1			382	8.1	8.2	9/10/85
7.55	1.8		.14	348	4.0	6.9	10/15/85
7.19	1.9			390	6.0	6.2	10/22/85
7.14				350	1.5	10.0	12/02/85
7.4	2.1			410	0	12.0	1/10/86
7.19	1.5			410	0	10.4	2/11/86
7.86	1.1				.2	12.2	3/10/86
8.47	.56			210	1.5	13.1	4/07/86
					7.2	10.7	4/28/86
8.75	0		0		7.5	10.8	4/29/86
8.95					7.9	9.9	4/30/86
9.25	1.3		0	101	7.9	10.0	5/02/86

East Pond water quality records.

Table 4

GASOMETER READINGS

Temp. C	Oxygen ppm	ΔP mm	Total Gas.%	N2 Sat. %	Oxygen Sat.%	Time	Date
7.2	17.4	115	115.8	107.6	143	1130am	4/28/86
7.2	17.4	137.5	118.9	111.5	143	1210pm	4/28/86
7.8	18.0	145	120.0	112.29	153	1245pm	4/28/86
7.5	13.3	18	102.3	100.44	109	825am	4/29/86
8.0	12	8	101.0	101.39	100.8	900am	4/30/86

Supersaturation levels of total gas, nitrogen, and oxygen in West Pond just after ice break-up. Barometric pressure is approx. 762 mm of mercury. Aerators turned on at 400pm 4/28/86.

Temp. C	Oxygen ppm	ΔP mm	Total Gas.%	N2 Sat. %	Oxygen Sat.%	Time	Date
7.2	10.7	42.5	105.8	110.2	88	1145am	4/28/86
7.5	10.8	2.5	100.3	103.3	90	850am	4/29/86
7.9	9.9	-8	98.96	105.96	83	930am	4/30/86

Supersaturation levels of total gas, nitrogen, and oxygen in East Pond just after ice break-up. Barometric pressure is approx. 762 mm of mercury. Aerators turned on at 400pm 4/28/86.

Table 5

measured. Many fish had white eyes, cataracts in the severest form. The reason for the high pH values was due to a high photosynthesis which reduced the carbon dioxide levels thus allowing the pH values to rise.

The Future

The trend today is toward rearing tanks and eventual raceway grow-out of trout, all using surface waters. This will entail the use of on-site oxygen generators. In some cases, clinoptilolite resins will no doubt be examined to enhance ammonia reduction where pH values allow. If algae becomes a problem because of nutrient levels then the pH-ammonia relationship will have to be dealt with.

As the trout farmer becomes more interested in the possibilities of year-round production, he is requesting education in water quality. We have found that instituting workshops and short courses increases his general knowledge of the industry before he finds himself in an unfavorable position. The new breed of trout farmers in Saskatchewan will be in a more favorable position to market a high quality product.

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